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*Indian Standard*  
GUIDE FOR TESTING OF  
CIRCUIT-BREAKERS WITH RESPECT TO  
OUT-OF-PHASE SWITCHING

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**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

# Indian Standard

## GUIDE FOR TESTING OF CIRCUIT-BREAKERS WITH RESPECT TO OUT-OF-PHASE SWITCHING

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( Continued on page 2 )

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*Indian Standard*

**GUIDE FOR TESTING OF  
CIRCUIT-BREAKERS WITH RESPECT TO  
OUT-OF-PHASE SWITCHING**

**0. F O R E W O R D**

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 12 March 1979, after the draft finalized by the High Voltage Switchgear and Controlgear Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Circuit-breakers, for which this guide is intended to apply, are those which are assigned an out-of-phase breaking capacity by the manufacturer. This assigned capacity is called for to meet out-of-phase conditions likely to occur in systems whose rated voltages exceed 1 000 V ac, specially to meet conditions of out-of-phase switching for tie line applications for 145 kV and above. The abnormal conditions could be one or a combination of several circumstances arising out of the out-of-phase conditions specified in 2.1. This guide is intended for circuit-breakers meant to operate under a majority of such circumstances.

**0.3** This guide shall be used in conjunction with the following standards:

IS : 2516 ( Part I/Sec 2 )-1963 Alternating current circuit-breakers:  
Part I Requirements, Section 2 Voltage range 1 000 to 11 000 volts

IS : 2516 ( Part I/Sec 3 )-1972 Alternating current circuit-breakers:  
Part I Requirements, Section 3 Voltage range above 11 kV

IS : 2516 ( Part II/Sec 2 )-1965 Alternating current circuit-breakers:  
Part II Tests, Section 2 Voltage above 1 000 up to and including  
11 000 volts

**0.4** In the preparation of this standard, assistance has been derived from the following publications issued by the International Electrotechnical Commission:

IEC Pub 56-4 ( 1972 ) High voltage alternating current circuit-breakers Part 4: Type tests and routine tests.

IEC Pub 267 ( 1968 ) Guide to the testing of circuit-breakers with respect to out-of-phase switching

**0.5** In order to facilitate comparison with the international standards and for ease of reference, the committee responsible for the preparation of this standard decided to indicate the major differences between Indian Standard and corresponding IEC Publications. This standard corresponds appreciably to IEC Publications referred to in **0.4** and there is no major differences.

**0.6** For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960\*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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## **1. SCOPE**

**1.1** This standard applies to all types of circuit-breakers with rated voltages above 1 000 V intended to be used for switching the connection between two parts of a three-phase system, during out-of-phase conditions.

*Note — The tests specified in this standard are made only if an out-of-phase breaking capacity has been assigned to the circuit-breaker by the manufacturer.*

## **2. TERMINOLOGY**

**2.0** For the purpose of this standard, the following definitions, in addition to those given in IS : 1885 (Part XVII) -1969†, shall apply.

**2.1 Out-of-Phase Conditions** — Abnormal circuit conditions of loss or lack of synchronism between the parts of an electrical system on either side of a circuit-breaker in which, at the instant of operation of the circuit-breaker, the phase angle between rotating vectors representing the generated voltages on either side, exceeds the normal value and may be as much as 180° (phase opposition).

**2.2 Out-of-Phase (as Prefix to a Characteristic Quantity)** — A qualifying term indicating that the characteristic quantity applies to operation of the circuit-breaker in out-of-phase conditions.

## **3. ASSIGNED OUT-OF-PHASE BREAKING CAPACITY**

**3.1** The assigned out-of-phase breaking capacity is the maximum out-of-phase breaking current that the circuit-breaker shall be capable of breaking at an out-of-phase recovery voltage equal to that specified in **5.6**, and under prescribed conditions. If a circuit-breaker has an assigned

\*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part XVII Switchgear and controlgear.

out-of-phase breaking capacity, this shall be 25 percent of the rated symmetrical (short-circuit) breaking capacity expressed in kiloamperes, unless otherwise specified.

For circuit-breakers which have an assigned out-of-phase breaking capacity, this shall be indicated on the name plate.

#### **4. STANDARD CONDITIONS OF USE WITH RESPECT TO THE OUT-OF-PHASE BREAKING CAPACITY**

**4.1** The standard conditions of use with respect to the out-of-phase breaking capacity are as follows:

- a) Opening and closing operations carried out in conformity with the instructions given by the manufacturer for the operation and proper use of the circuit-breaker and its auxiliary equipment,
- b) Earthing condition of the neutral of the power system corresponding to that for which the circuit-breaker has been tested,
- c) Service frequency within  $\pm 10$  percent of the rated frequency of the circuit-breaker, and
- d) Absence of a fault on either side of the circuit-breaker.

**NOTE 1** — All circuit-breakers having an assigned out-of-phase breaking capacity shall make the circuits to which their assigned out-of-phase breaking capacity applies ( *see 5.9* ).

**NOTE 2** — The requirements of this guide cater for the great majority of applications of circuit-breakers intended for switching during out-of-phase conditions. Several circumstances would have to be combined to produce a severity in excess of those covered by the tests given in this standard and, as switching during out-of-phase conditions is rare, it would be uneconomic to design circuit-breakers for the most extreme conditions. Where frequent out-of-phase switching operations are anticipated, or where for other reasons out-of-phase switching is a matter of importance, the user should consider determining actual system recovery voltages. A special circuit-breaker, or one rated at a higher voltage, may sometimes be required. As an alternative solution, the severity of out-of-phase switching duty is reduced in several systems by using relays with coordinated impedance sensitive elements to control the tripping instant, so that interruption will occur either substantially after or substantially before the instant the phase angle is  $180^\circ$ . Both probability and transient voltage can benefit greatly from arranging relays to trip both ends of a line simultaneously.

#### **5. OUT-OF-PHASE BREAKING CAPACITY TESTS**

##### **5.1 General**

**5.1.0** Tests shall be made to determine the ability of a circuit-breaker to break and make currents during out-of-phase conditions.

**5.1.1** The tests shall be made single phase if the conditions for tests on single pole units in accordance with **7.5.1** of IS : 2516 ( Part II/Sec 2 )-1965\* are fulfilled. If these conditions are not fulfilled, three-phase tests should be made. Unit tests may be made provided the conditions specified below are satisfied:

a) *Identical nature of the units* — The units of the circuit-breaker shall be identical in their shape, in their dimensions and in their operating conditions; only the devices for controlling the voltage distribution among units may be different. In particular, the following conditions shall be fulfilled:

1) *Simultaneous operation of contacts* — The opening, in breaking tests, or closing, in making tests, of the contacts of one pole shall be practically simultaneous.

This condition shall be considered as fulfilled if the opening or closing of the contacts of the unit which is the last to operate takes place, at the latest, one quarter cycle of rated frequency after the opening or closing of the contacts of the unit which operates first.

2) *Supply of the arc-extinguishing medium* — For a circuit-breaker using a supply of arc-extinguishing medium from a source external to the units, the supply to each unit shall for all practical purposes be independent of the supply to the other units, and the arrangement of the supply pipes shall be such as to ensure that all the units are fed practically simultaneously in an identical manner.

3) *Condition of the arc-extinguishing medium* — The design of the circuit-breaker and its units shall be such that during the breaking or making operations, the condition of the medium in which the arc is created ( for example, temperature, pressure, rate of flow, etc ) in each unit is for all practical purposes not influenced by the operation of the other units.

In particular, neither the supply of extinguishing medium to the unit or units under test, nor the ease of exhaust of products from the arc, shall be increased owing to the absence of arcing in the other units normally in series with the unit or units under test.

Any ionized gases or vapours which might be present in the exhaust shall not escape in such a manner as to cause malfunction of adjacent units or breakdown of the circuit-breaker owing to partial or complete sparkover.

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\*Alternating current circuit-breakers: Part II Tests, Section 2 Voltage above 1 000 up to and including 11 000 volts.

b) *Voltage distribution* — The voltage distribution between units of a pole as affected by the influence of earth shall be determined for the relevant test-circuit conditions laid down for tests on one pole. Where the units are not symmetrically arranged, the voltage distribution shall be determined also with reverse connections.

If the circuit-breaker is fitted with parallel resistors, the voltage distribution shall be calculated or measured statically at the equivalent frequency involved in the TRV.

**NOTE** — The equivalent frequency is deemed to be equal to  $\frac{1}{2}f_1$  in the case of four parameters or to  $\frac{1}{4}f_1$  in the case of two parameters [ *see Appendix A of IS : 2516 (Part I/Sec 3)-1972\** ].

For short-line fault unit tests, the voltage distribution shall be calculated or measured statically on the basis of a voltage on the line side at the fundamental frequency of the line oscillation and a voltage on the source side at the equivalent frequency of the TRV for terminal faults, the common point of the two voltages being at earth potential.

If only capacitors are used, the voltage distribution may be calculated or measured at power frequency.

The manufacturing tolerances for resistors and capacitors shall be taken into account. The manufacturer shall state the value of these tolerances.

**NOTE 1** — It shall be taken into account that the voltage distribution may be more favourable during the out-of-phase breaking tests than during the terminal or short-line fault short-circuit tests.

**NOTE 2** — The actual voltage distribution in a short-circuit breaking operation may be more linear than indicated by static measurements or calculations. If evidence of this can be produced, the voltage distribution derived from this evidence shall be used for the selection of the voltage for the unit tests.

**NOTE 3** — The influence of pollution is not considered in determining the voltage distribution. In some cases pollution may affect after this voltage distribution.

c) *Requirements for unit tests* — All unit tests shall be performed on the maximum number of units in series compatible with the capabilities of the testing laboratory, at the specified making and breaking currents.

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\*Alternating current circuit-breakers: Part I Requirements, Section 3 Voltage range above 11 kV.

When testing a single unit, the test-voltage shall be the voltage of the most highly stressed unit of the complete pole of the circuit-breaker determined in accordance with (b) above. For short-line fault conditions, the unit referred to is that most highly stressed at the specified time of the first peak of the side line transient voltage.

When testing a group of units, the voltage appearing at the terminals of the most highly stressed unit of the group shall be equal to the voltage of the most highly stressed unit of the pole, both determined in accordance with (b) above.

In unit tests, the insulation to earth is not stressed with the full voltage occurring during a breaking operation of the complete circuit-breaker. For certain types of circuit-breakers such as circuit-breakers in metal enclosures, it may be necessary to prove that the insulation to earth is capable of withstanding this full voltage.

**5.1.2** The out-of-phase breaking capacity performance in a test shall be stated in terms of:

- a) the value of the out-of-phase breaking current,
- b) the value of the out-of-phase recovery voltage, and
- c) the values of the parameters of the inherent out-of-phase restriking voltage [ *see* Appendix A of IS : 2516 ( Part I/Sec 3 )-1972\* ].

## **5.2 Conditions of Severity for Out-of-Phase Breaking Capacity Tests**

**5.2.1** The out-of-phase breaking capacity tests shall be carried out under the conditions of severity specified in the following:

- a) Arrangement of circuit-breaker for tests (*see* 5.3),
- b) Behaviour of circuit-breaker during tests (*see* 5.4),
- c) Condition of circuit-breaker after tests (*see* 5.5),
- d) Test voltage (*see* 5.6),
- e) Test frequency (*see* 5.7),
- f) Test circuit (*see* 5.8), and
- g) Test duties (*see* 5.9).

## **5.3 Arrangement of Circuit-Breaker for Tests**

**5.3.1** The circuit-breaker subjected to out-of-phase breaking capacity tests shall be a complete assembly with its own operating devices and shall truly represent its own type in all details of construction and operation as recorded in certified drawings and/or schedules.

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\*Alternating current circuit-breakers: Part I Requirements, Section 3 Voltage range above 11 kV.

**5.3.2** Power operating devices shall be operated at the specified minimum operating voltage and/or the specified minimum operating pressure.

**5.3.3** The air or gas pressure in air or gas-blast breakers shall be the minimum operating pressure for the rated (short-circuit) breaking capacity.

**5.3.4** A single-pole unit of the circuit-breaker, or a pole of a complete circuit-breaker to be tested, shall be equivalent to, or not in a more favourable condition than, the complete three-phase circuit-breaker in respect of:

- a) speed of make and break,
- b) arc-extinguishing medium,
- c) power and strength of operating mechanism, and
- d) rigidity of the structure.

#### **5.4 Behaviour of Circuit-Breaker During Tests**

**5.4.1** When performing any test duty up to its assigned out-of-phase breaking capacity, the behaviour of the circuit-breaker shall comply with the following conditions:

- a) During operation, the circuit-breaker shall not show signs of undue stress. For oil circuit-breakers, there shall be no outward emission of flame, and the gases produced, together with the oil carried with the gases, shall be conducted from the circuit-breaker and directed in such a way as not to impair the insulation.
- b) For air or gas-blast circuit-breakers, flame or metallic particles, such as might impair the insulation level of the circuit-breaker, shall not be projected beyond the boundaries specified by the manufacturer.

#### **5.5 Condition of Circuit-Breaker After Tests**

**5.5.1** After performing the tests specified in 5.9, the mechanical parts and insulators of the circuit-breaker shall be practically in the same condition as before the performance and the circuit-breaker shall be capable of making, carrying and breaking its rated normal current at its higher rated voltage, although the making capacity and the breaking capacity of the circuit-breaker may be materially reduced.

**5.5.2** Between test duties, the circuit-breaker may be inspected. In the circumstances indicated in 5.9, the circuit-breaker may be restored to its initial condition by maintenance work as, for example:

- a) repair or replacement of the arcing contacts and any specified renewable parts;

- b) renewal or filtration of the oil or of any other extinguishing medium, and addition of any quantity of the medium necessary to restore its normal level; and
- c) removal from the insulators of deposits caused by decomposition of the extinguishing medium.

## 5.6 Test Voltage

**5.6.1** For single-phase tests, both the applied voltage and the recovery voltage shall, as nearly as possible, equal to one of the following values (*see also 4, Note 2*):

- a) For circuit-breakers intended to operate in systems with effectively earthed neutral [*see IS : 2165 (Part I)-1973\**], 2·0 times the higher rated voltage of the circuit-breaker divided by  $\sqrt{3}$ .
- b) For circuit-breakers intended to operate in systems other than with effectively earthed neutral, 2·5 times the higher rated voltage of the circuit-breaker divided by  $\sqrt{3}$ .

**5.6.2** For three-phase tests, the recovery voltage of the first pole to clear shall have the appropriate value stated above for single-phase tests.

**5.6.3** The inherent restriking voltage of the test circuit shall have an amplitude factor of 1·25 and a natural frequency equal to 50 percent of that corresponding to the rated (short circuit) breaking capacity of the circuit-breaker.

**5.7 Test Frequency** — For circuit-breakers with rated frequency of 50 Hz or 60 Hz, the tests shall be carried out at a frequency between 45 Hz and 63 Hz. For other circuit-breakers, the tests shall be carried out at the rated frequency of  $\pm 10$  percent or according to agreement between the user and the manufacturer.

## 5.8 Test Circuit

**5.8.1** The power factor of the test circuit shall not exceed 0·15.

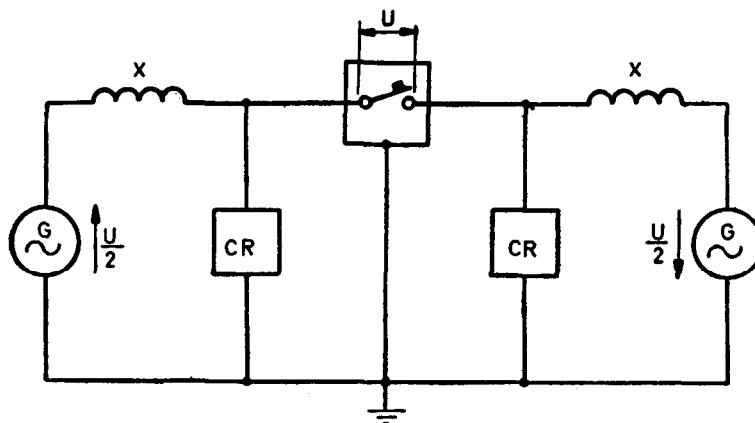
**5.8.2** For single-phase tests, the test circuit shall be so arranged that one half of the applied voltage and of the restriking voltage is on each side of the circuit-breaker (*see Fig. 1*).

If it is not possible to use this circuit in the testing station, it is permissible to use two identical voltages separated in phase by 120 electrical degrees, instead of 180, provided that the total voltage across the breaker is as stated in 5.6 (*see Fig. 2*).

Tests with one terminal of the circuit-breaker earthed are permissible only with special agreement of the manufacturer (*see Fig. 3*).

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\*Insulation coordination: Part I Dimensions and basic principles (*first revision*).

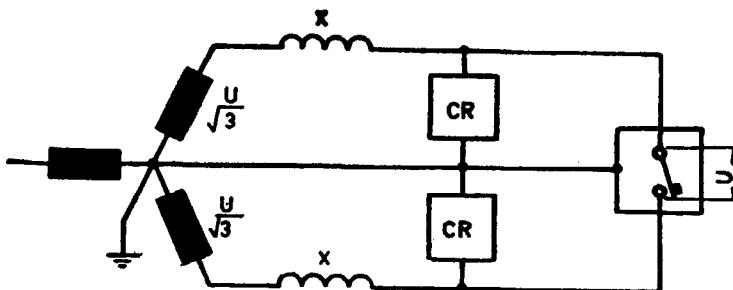


*CR* — combinations of capacitances and resistances

*X* — reactance

*G* — generator

FIG. 1 CIRCUIT FOR SINGLE PHASE TEST (180° OUT-OF-PHASE)

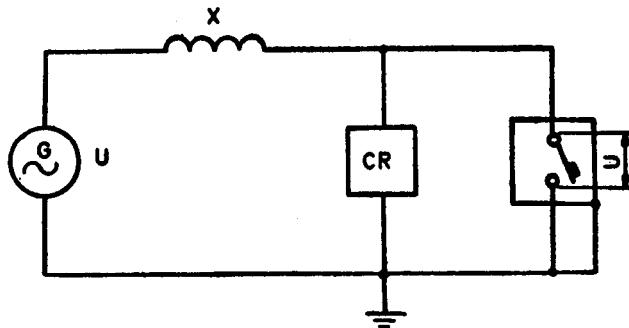


*CR* — combinations of capacitances and resistances

*X* — resistance

FIG. 2 CIRCUIT FOR SINGLE PHASE TEST (120° OUT-OF-PHASE)

**5.8.3** Three-phase tests, with the three terminals on one side of the circuit-breaker earthed or with the star point of the supply earthed, are permissible only with special agreement of the manufacturer (*see* Fig. 4), especially for circuit-breakers intended to operate in systems other than with effectively earthed neutral.



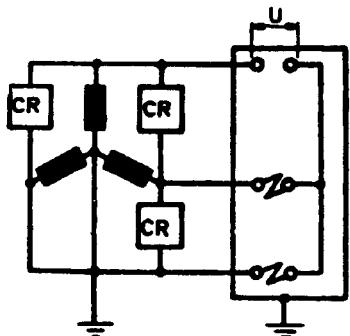
CR — combinations of capacitances and resistances

X — reactance

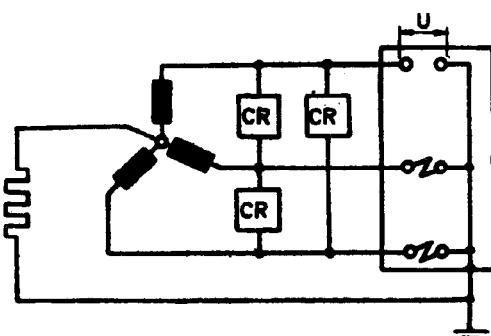
G — generator

FIG. 3 ALTERNATE CIRCUIT FOR SINGLE PHASE TEST

In accordance with Fig. 4A, the neutral of the supply source may be earthed through a resistor, the resistance of which should be as high as possible and expressed in ohms, in no case less than  $E/10$ , where  $E$  is the numerical value in volts of the phase-to-phase voltage of the test circuit.



4A



4B

CR — combinations of capacitances and resistances

FIG. 4 CIRCUITS FOR THREE PHASE TESTS

## 5.9 Test Duties

5.9.1 The test duties to be made are indicated in Table 1.

TABLE 1 SYMMETRICAL BREAKING CURRENT FOR TEST DUTIES

TEST DUTY	DUTY CYCLE	SYMMETRICAL BREAKING CURRENT IN PERCENT OF THE ASSIGNED OUT-OF-PHASE BREAKING CAPACITY
(1)	(2)	(3)
1	O and O	20 to 40
2	O and CO	100 to 110

The time interval between the two tests in each duty shall be sufficient to permit the circuit-breaker to return to its initial condition.

In test duty No. 1, the value of the dc component of the current is not prescribed.

In test duty No. 2, the value of the dc component of the current shall be:

- for the first breaking operation, not more than 20 percent of the ac component; and
- for the second breaking operation, not less than that specified in Fig. 4 of IS : 2516 ( Part II/Sec 2 )-1965\*.

In the making operation of test duty No. 2, the prospective peak making current shall not be less than 2.5 times the assigned out-of-phase breaking capacity.

5.9.2 For circuit-breakers which can break within the first half cycle after contact separation, the instant of contact separation shall be chosen so as to produce the most unfavourable conditions. Sufficient tests shall be made, or evidence produced, to show that the right choice has been made.

5.9.3 No reconditioning of the circuit-breaker is permissible in the course of the four tests. However, where additional tests become necessary, reconditioning of the circuit-breaker in accordance with 5.5 is permitted and only a repeat of the particular test duty is then required.

\*Alternating current circuit-breakers: Part II Tests, Section 2 Voltage above 1 000 up to and including 11 000 volts.

### 5.10 Test Report

5.10.1 The test report shall contain the data necessary to prove that the circuit-breaker complies with this guide. Oscillographic and other records shall include:

- a) short-circuit current in each phase;
- b) voltage across each phase;
- c) instant of energizing trip-coil;
- d) travel of moving contacts, if practicable;
- e) current in closing coil;
- f) timing wave;
- g) gas pressure before test;
- h) voltage of the supply circuit;
- j) break time; and
- k) transient recovery voltage.

**Note** — Any deviation from strict compliance with this guide shall be clearly stated in the test report.

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